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ARPA Network Contract
1973 ARPA Project Summary

Prepared for : ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by Frank E. Heart
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During 1973 the network continued to expand at a healthy rate, and fostering this expansion continued to occupy a central place in the group's activities. The number of nodes on the net increased from 35 to 45, up 30%; geographical expansion was also noteworthy, with one of the new nodes located at the Norwegian Seismic Array in Kjeller, Norway, and another at the University of London in England. Comparable growth was exhibited in the number of Host computers connected (approximately four dozen at the end of 1973), the volume of traffic on the net (grew by 250% to 2.75 million packets per day), and the number of individuals making use of the network's facilities. A figure for the latter is difficult to determine with any accuracy, but at a recent count the Network Information Center recognized the identities of some 2,000 users.

Other activities of particular interest have included the following:

Four "Very Distant Host" interfaces were installed during 1973. The VDH option enhances network accessibility by allowing computers to connect to the network over error-controlled communications circuits.

All IMPs and TIPS in the network received memory retrofits during the year in order to improve performance and allow addition of new logical features; other hardware changes were implemented to permit more flexible configuration and improved reliability.

Improvements were made in the performance of the TIP, including better handling of modems and high speed lines, improved services from the TENEX Resource Sharing Exec, and the adaptation to new kinds of terminals. A notion which has aroused considerable interest is the TIP's automatic remote use of TENEX, allowing a small machine to exhibit large machine behavior.

A continuing effort on network reliability has included sizable software changes in the IMPs and TIPS to checksum data structures, routing code, and routing messages in order to reduce the sensitivity of the net to hardware failures. Other reliability efforts included the completion of an auto-dialer facility for testing TIP ports nationwide, improvements in trouble reports from the IMPs to the Network Control Center, and a very large amount of attention to detailed IMP, TIP, modem, terminal, and Host

connection troubles of all kinds.

A major group effort continued on the design and construction of a new modular line of IMPs based on the Lockheed SUE. By the end of 1973, an 11-processor version of the High-Speed IMP was operating, and packets had moved between an old style IMP and a SUE-based IMP. Designs were complete for all special BBN cards, and most cards were in production form.

Two satellite IMPs were completed and tested with initial versions of the software; investigations of broadcast algorithms continued.

We commenced a multi-stage change in the routing algorithms of the net. By the end of 1973, changes had included improved routing propagation and the ability to handle low speed circuits properly, for example, the link to Norway.

We played a leading role in the codification of new Telnet and file transfer protocols and participated in the study of protocols for international network interworking.

We designed and began implementing a "Private Line Interface" mini-Host to permit use of the network for secure traffic.

We continued working on and have now nearly completed a "Remote Job Entry" mini-Host to permit connection of RJE terminals to the network.

Finally, a major effort in addition to the activities above was explaining those activities to the public, in the form of conference participation, entertaining of visitors, and documentation. Most of our existing manuals underwent at least one, and more often several, major revisions; three new volumes were completed (and then regularly updated): the documentation of the IMP, the TIP, and the Network Control Center programs. A long array of visitors included delegations from Japan and the People's Republic of China. Professional papers written during the year included: "An Advanced Computer Communication Network," for the AIAA Computer Network Systems Conference; "A New Minicomputer/Multiprocessor for the ARPA Network," for the 1973 NOCE; "The ARPA Network," for the NATO Advanced Studies Institute in Brighton, England; "Reliability Issues in the ARPA Network," for the ACM/IEEE 3rd DATACOMM; "Design Considerations for Routing Algorithms in Computer Networks," "The BBN Multiprocessor," and "The Satellite IMP for the ARPA Computer Network," all for HICSS-7 1974; and "Some Computer Network Interconnection Issues," for the 1974 NOCE.

ARPANET MANAGEMENT STUDY

1973 ARPA Project Summary
Paul Baran, Principal Investigator

Cabledata Associates, Inc.
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OBJECTIVE

This research effort explored the question of possible divestiture of the ARPANET. We sought to derive a policy basis which would encourage rapid technological transfer of packet switching and resource sharing to serve non-experimental DoD and other national requirements; to simplify ARPA's management task; and to aid the state-of-the-art of netted information processing.

An intermediate objective was to determine and document the expected technological evolution of the potential marketplace, industry structure, regulatory climate and real-world constraints limiting the directions for the future evolution of the ARPANET.

GENERAL ACCOMPLISHMENTS

As a result of detailed exploration of the technical, economic, legal, institutional and regulatory implications of alternative ownership and management policies, Cabledata Associates believes it has identified a specific preferred policy significantly more desirable than others considered.

A detailed specific plan of action has been submitted to ARPA. This plan calls for dividing the functions of the ARPANET into two categories: those necessary for conducting communications networking experiments, and those that provide communications service support of ARPA contractors and government agencies. The plan proposes divesting only part of the ARPANET on a test incremental basis and encouraging commercial cross connection with the ARPANET, also on an experimental basis. Only after documentation of performance better than that presently experienced should the divestiture be made complete.

SPECIFIC IMPACTS ON ARPA

1. The plan allows ARPA to continue networking research without interference with the provision of high reliability services to those presently using the network as a way of meeting day-to-day computer-based work requirements.
2. The plan appears to eliminate the pressures of increasing demands upon ARPA to supply other agencies of government, research organizations and commercial endeavors with special arrangements for connection to the ARPANET.
3. The plan minimizes pressures for exogenous governmental regulation on packet switching and computer netting communication by encouraging the creation of competition for potential service suppliers.
4. The plan permits ARPA to give more attention to its primary charter function and, in conformity with ARPA's long-range objectives, seeks to gracefully remove ARPA from its present role as a supplier of network services.

NATIONAL LONG-TERM IMPACTS

1. The present trajectory of commercial network evolution suggests that a number of separate and duplicative networks will be built. It appears to be in the short-term self-interest of each component sub-network to restrict information flows from other sub-networks. This could seriously limit the rate of development of the nation's resource sharing capability.
2. A plan of action is presented which appears to form a viable alternative. It is both legally acceptable and economically attractive to potential new industry entrants. Successful implementation could, in the long term, aid the evolution of a national (and later, international) unified information networking capability.

3. The proposed plan acknowledges present communications regulatory policy; the legal constraints involved in the use and in the divestiture of federally developed and owned resources; and the realities of the marketplace.

4. The proposed plan appears to overcome the institutional dilemma of creating a long-term competitive environment which both discourages formation of monopoly or oligopoly structure and also encourages close working relationships and the sharing of common resources where natural monopoly contours exist.

5. A framework is proposed that allows the network to evolve to a larger structure of individually owned and operated networks which nevertheless fully cooperate with one another. From the users' viewpoint, the network could eventually appear as a single system and not a set of sub-networks unable to talk to one another. The plan seeks benefits similar to those found in a single integrated telephone system, where each user is potentially able to communicate with any other subscriber in the world.

6. The plan is based on a belief that it is in the nation's interest to evolve to a capability of universal potential interconnection in which any user of digital information can (upon mutual agreement) exchange data with any other such user in the nation, with no requirement for special connections or equipment.

7. The plan seeks evolution away from arbitrary data flow blockages by institutional and regulatory constraints held over from previous eras.

8. The plan is intended to implement policy and technological changes permitting ARPA to assist commercial growth toward a unified national information transfer network suitable for resource sharing. Specifically, it proposes that ARPA exercise leverage, using its investment in the ARPANET as a carrot, to shape the early development of the packet switching industry.

ACHIEVEMENTS

If successfully implemented, the proposed plan could aid the eventual development of resource sharing in the longer term in a manner which is in greater consonance with national policy objectives than the present trajectory. Such objectives include: increasing the effectiveness of DoD computer resource usage; improving national productivity by more efficient and widespread use of computing resources; and aiding the U.S. balance of trade position by helping to maintain present U.S. leadership of the information processing industry.

It appears that evolution of the computing resource sharing industry is more limited by institutional constraints than by technological capabilities. If this assertion is correct, then the potential economic payoff in accelerating the development of resource sharing can be sizable, making it even more difficult to estimate the magnitude of the possible impact.

1973 ARPA PROJECT SUMMARY

PREPARED FOR: ARPA IPT PRINCIPAL INVESTIGATORS CONFERENCE
LOS ANGELES, FEB 6-8, 1974

PREPARED BY: PROF. HUGH FOLK
CENTER FOR ADVANCED COMPUTATION
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FOLLOWING ARE THE MAJOR ACCOMPLISHMENTS AT THE CENTER FOR
ADVANCED COMPUTATION DURING THE 1973 CALENDAR YEAR:

APPLIED MATHEMATICS GROUP:

- IMPLEMENTATION OF THE LINEAR PROGRAMMING SYSTEM ON ILLIAC IV.
- STUDIES FOR EFFICIENT PARALLEL ALGORITHMS FOR FINDING LEADING EIGENVALUES AND VECTORS OF LARGE SPARSE REAL SYMMETRIC MATRICES WERE COMPLETED.
- REDUCING NUMBER OF OPERATIONS FROM N^3 TO N^2 IN UPDATING SOLUTION OF SYSTEMS OF LINEAR EQUATIONS.
- A DIRECT METHOD FOR SYSTEMS FOR SYNTHESIS OF MAGNETIC RESONANCE WAS DEVELOPED.
- A MATRIX GENERATOR LANGUAGE, TO ALLOW RAPID SPECIFICATION OF LARGE MATRICES IS BEING DEVELOPED.
- DEVELOPMENT OF A SECURITY CODE FOR THE ARPA NET WAS COMPLETED.

ILLIAC IV MULTISPECTRAL IMAGE PROCESSING:

AN ILLIAC IV MULTISPECTRAL IMAGE ANALYSIS SYSTEM IS NEARING COMPLETION. THE SYSTEM DIGITALLY INTERPRETS LARGE QUANTITIES OF ERTS SATELLITE MULTISPECTRAL SCANNER IMAGERY.

ILLIAC IV PROGRAMS TO ENABLE MULTIVARIATE CLUSTER ANALYSIS AND STATISTICAL CLASSIFICATION PATTERN RECOGNITION WERE DEVELOPED IN SUPPORT OF THE SYSTEM.

ALSO, A GENERALIZED "TEMPLATE MATCHING" PATTERN RECOGNITION SYSTEM HAS BEEN FOUND AND IS NOW BEING FURTHER INVESTIGATED.

NETWORK TERMINAL SYSTEMS PROJECT:

- ANTS USERS GROUP MEETING HOSTED APR 29-MAY 1 1973. AN ANTS STEERING COMMITTEE WAS CREATED BY ARPA-IPT IN SEPTEMBER TO REPRESENT THE ARPA ANTS USER COMMUNITY'S INTEREST IN FUTURE ANTS DEVELOPMENT.
- PEESPOL (PDP-11 EXECUTIVE SYSTEM PROGRAM ORIENTED LANGUAGE) WAS DESIGNED AND IMPLEMENTED FOR THE PURPOSE OF CREATING A HIGH LEVEL IMPLEMENTATION LANGUAGE FOR PDP-11 SYSTEMS PROGRAMMING. DURING 1973 SEVERAL ADDITIONS AND ENHANCEMENTS WERE MADE TO THE PEESPOL COMPILER.
- THE FANCY ARPA NETWORK GRAPHICS SYSTEM (FANGS) WAS COMPLETED AT THE UCSD B6700 SYSTEM.

DISTRIBUTED SYSTEMS GROUP:

DISTRIBUTED SYSTEMS OF DISSIMILAR COMPUTERS WERE STUDIED. EMPHASIS WAS PLACED ON DETERMINING THE COST, PERFORMANCE AND RELIABILITY IMPROVEMENTS AVAILABLE IN A SHARED RESOURCE ENVIRONMENT.

PRELIMINARY RESULTS INDICATE THAT:

- PL/I IS A SUITABLE LANGUAGE FOR SOFTWARE DEVELOPMENT IN A MULTI-MACHINE ENVIRONMENT.
- SIGNIFICANT IMPROVEMENTS IN COSTS AND RESPONSE TIME ARE EVIDENT WHEN THE BEST MACHINE IS SELECTED FOR A GIVEN TASK.

ILLIAC IV SUPPORT GROUP:

NUMEROUS TENEX UTILITY PROGRAMS WERE DEVELOPED IN SUPPORT OF CAC ILLIAC IV PROGRAMMERS. PROGRAMS INCLUDED:

- TRANSFORMING SEQUENCE-NUMBERED SOURCE FILES FROM OTHER NETWORK SITES INTO MINIMUM-SIZED TENEX COMPATIBLE SOURCE FILES.
- ALLOWING USERS TO EXAMINE AN ILLIAC IV DUMP FILE, REMOVE DATA FROM IT, AND TO INSERT DATA FILES INTO IT.
- A HOST OF SMALL PROGRAMS TO MANIPULATE, INSPECT, AND COMPARE FILES .

AS AN EARLY PART OF CAC'S EFFORT TO RUN PREVIOUSLY DEVELOPED PROGRAMS ON ILLIAC IV, A FAST FOURIER TRANSFORM PROGRAM WAS CORRECTLY EXECUTED. THIS WAS AMONG THE FIRST PROGRAMS RUN BY NON-AMES (SYSTEM) PROGRAMMERS ON THE ILLIAC, AND UNCOVERED SEVERAL HARDWARE ERRORS IN THE ROUTING LOGIC OF THE MACHINE.

LATE IN THE YEAR , PRELIMINARY WORK ON THE DESIGN OF A PARALLEL PROCESSOR PERIPHERAL TO THE 360/195 AT THE NASA GODDARD INSTITUTE FOR SPACE STUDIES WAS BEGUN.

ENERGY RESEARCH GROUP:

AN ENERGY DATA BASE HAS BEEN ASSIMILATED AT THE CENTER FOR ADVANCED COMPUTATION, CONSISTING OF TWENTY-FOUR 400 X 400 MATRICES AND 400 ELEMENT VECTORS , AND ASSOCIATED COMPUTER SOFTWARE (FOR EXAMPLE ROUTINES FOR AGGREGATION, DISAGGREGATION, TAX AND PRICE PASS-THROUGH).

A SOPHISTICATED ENERGY-EMPLOYMENT MODEL IS IN THE PROCESS OF DEVELOPMENT TO BE USED VIA REMOTE TERMINAL BY A RESEARCHER RELATIVELY UNSKILLED IN COMPUTER INTERACTION. ACCESS AT VERY REASONABLE COST IS NOW AVAILABLE TO THE COMMERCE DEPARTMENT THROUGH THE NATIONAL BUREAU OF STANDARDS' LINK ON THE ARPA NETWORK.

THE ENERGY RESEARCH GROUP IS ALSO CAPABLE OF MANAGING THE DATA BASE FOR THE GENERAL USER FOR THE YEAR OR SO THAT WOULD BE REQUIRED TO ESTABLISH IT AS OPERATIONAL. MANAGEMENT OF THE DATA BASE ENTAILS THE SELECTION OF ONLY QUALIFIED AND DOCUMENTED DATA SETS AND THE DEVELOPMENT OF THE COMPUTER LANGUAGE SYSTEMS TO HANDLE THE MODEL.

IT IS HOPED THAT BY ESTABLISHING A NATIONAL ENERGY DATA BASE, DATA AND MODELING TECHNIQUES CAN BE EXPOSED TO PUBLIC SCRUTINY? MISAPPLICATION AND MISTAKES CAN THEN BE REDUCED AND THE UNDER-UTILIZATION OF SOME OF THE MORE POWERFUL TECHNIQUES CAN BE REDUCED.

PACKET RADIO COMMUNICATIONS
1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by: Francis Dickson
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This project is one part of a larger effort directed at extending the packet switching technology to include a flexible access and distribution capability for resource sharing networks. The objectives of the Collins investigations are: (1) Perform research covering the application of radio frequency technology to packet switching/communications, (2) Participate in the overall ARPA Packet Communications Technology Program under the guidance of the Packet Radio Communications Working Group and (3) Provide experimental equipments to support propagation/noise measurements and packet radio network experiments.

Theoretical studies and laboratory experiments are being conducted in each of the following areas:

1. Radio Networks - identification and evaluation of alternative network structures and operating disciplines.
2. LOS Transmission - parametric analysis of the transmission variables such as operating frequency, area coverage, interference, power output and path losses.
3. Modulation and Detection - analysis of signal processing techniques as related to contention, channelization and coexistence properties.
4. Equipment Design - identification and characterization of economic and technical constraints and limitations.
5. Communications Security - evaluate the impact of encryption and traffic flow security requirements and disciplines on system design.

The interim results of these continuing investigations have been reported in 15 Packet Radio Temporary Notes and 2 Security Memorandums distributed this year.

In August, 1973, the need for special test equipment to support a planned series of propagation and noise measurements was identified. A dual frequency (430 MHz and 1325 MHz) spread spectrum test set was defined. This equipment was designed and constructed and integrated into the measurements program in December of 1973.

The following statements summarize the significant calendar 1973 results:

1. Upper and lower bounds on the frequency band for the initial Packet Radio experiments have been established.
2. Several computer-aided design programs have been developed and used for signal processing analysis and evaluation.
3. A family of microprocessor chips has been selected for implementing the digital functions of the experimental repeater.
4. A basic propagation model has been identified and performance bounds established.
5. A dual frequency, dual chip rate, spread spectrum test set (transmitter and receiver) has been developed and integrated into the measurements system.
6. Equipment designs have been outlined for several candidate channelization schemes to demonstrate the tradeoffs between system parameters and equipment complexity.
7. Laboratory test data has been generated on broadband antenna structures, Surface Acoustic Wave Devices (SAWD) and power amplifiers. These test results are compared with the theoretical performance.

The 1974 efforts will be concentrated on establishing the performance parameters desired for the initial experimental equipment and the design, construction and testing of a prototype repeater for use in the initial channel and network experiments.

Datacomputer Project
1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by: Thomas M. Marill
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The goal of the project continues to be the development of a shared, large-scale data storage utility, to serve the needs of the Arpanet community.

The system under development will make it possible to store within the network such files as the ETAC Weather File or the NMRO Seismic Data File, which are measured in hundreds of billions of bits, and to make arbitrarily selected parts of these files available within seconds to sites requesting the information. The system is also intended to be used as a centralized facility for archiving data, for sharing data among the various network hosts, and for providing inexpensive on-line storage to sites which need to supplement their local capability.

Logically, the system can be viewed as a closed box which is shared by multiple external processors, and which is accessed in a standard notation, "datalanguage". The processors can request the system to store information, change information already stored in the system, and retrieve stored information. To cause the datacomputer to take action, the external processor sends a "request" expressed in datalanguage to the datacomputer, which then performs the desired data operations.

From the user's point of view the datacomputer is a remotely-located utility, accessed by telecommunications. It would be impractical to use such a utility if, whenever the user wanted to access or change any portion of his file, the entire file had to be transmitted to him. Accordingly, data management functions are performed by the datacomputer itself. The user sends a "request", which causes the proper functions to be executed at the datacomputer without requiring entire files to be shipped back and forth.

NIC 20784
Part of NIC 20414

During 1974 the datacomputer system achieved its initial operating capability on the Arpanet, and a number of host sites began using the service on a routine basis. Statistics collected during July indicate that the number of weekly connections to the datacomputer averaged about 500. The service is based on Version 0/9, which was completed in June 1973. (Previous versions of the system had been used only for demonstration and for internal CCA development purposes.) Version 0/9 offers a (somewhat primitive) subset of the capabilities of the full datalanguage. Succeeding versions will provide increased datalanguage capabilities. The next version, 0/10, has been largely completed and will start offering service in the spring of 1974.

Currently, only disk storage is available internally to the datacomputer system. During 1974 the total disk storage was increased from 0.9 to 2.3 billion bits. Plans call for the addition of 180 billion bits of tertiary storage to the CCA site in 1974. Since datalanguage is device-independent, these increases in storage capacity will not affect the user programs running on network hosts.

In addition to using the dedicated equipment at CCA it is planned that datacomputer service will also make use of hardware resources located at NASA/Ames, using CCA software. The two sites will provide mutual backup for one another, thereby guarding against accidental loss of data and providing for satisfactory uptime of the overall service.

Based on the results with datalanguage to date, a major design iteration of the language has begun. Specifications for the enhanced language will be made available in 1974.

FORUM

1973 ARPA Project Summary

A NETWORK CONFERENCING SYSTEM FOR POLICY FORMULATION

Institute for the Future
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Menlo Park, California 94025

Roy Amara and Jacques Vallee

The Institute for the Future is a nonprofit organization concerned with the development of long-range planning tools. In March 1972 it began a study of computer-based conferencing systems, leading to the implementation of a system called FORUM which became operational during 1973 at two sites (BBN and USC-ISI) on ARPANET.

This project is developing a geographically distributed group-via-computer management tool. New equipment is being designed and programs are being written to automate the extraction and collation of expert opinion.

The thrust of the project phase completed this year was to develop computer-based techniques for the rapid extraction and evaluation of judgments from geographically dispersed participants, but where full decision-making power must be reserved by a single executive responsible for the decision.

This line of research and development is not entirely new, and major efforts in this field have gone before. Where we hope that our work will differ from earlier efforts is in that we seek to develop a "practical" system that will be useful as a real-world, real-time management tool. FORUM is also unique in its ability to support synchronous discussions and to provide on-line retrieval of information.

During the course of this first phase of the project, we have reduced this distance between today's state of the art and the requirements of a practical, usable system. During 1973, FORUM has left the demonstration stage. In May 1973, a conference linking three groups of energy experts (located in Washington, D.C., in Colorado, and in California) and the Institute staff with direct access to large data-bases showed the applicability of the system to real-world problems. In the second half of 1973, FORUM has been used extensively by research groups outside the Institute, and a version of

the system has been made available to ARPA for its own operations. The acid test of practicality is whether the system will in fact be employed by management in their day-to-day operations.

The basic idea of FORUM is to allow unhampered interaction of experts under the guidance of an "organizer" who (1) defines the topic of a discussion; (2) assembles a panel of experts or participants on that topic; and (3) presents the initial background material relevant to the subject. Each participant communicates with the computer network via a convenient terminal. FORUM conveys questions and answers, assembles group opinions, protects anonymous statements, and supplies other information to and within the group while the chairman monitors the proceedings and intervenes as necessary.

An important facet of FORUM conferences lies in the ability of the participants to easily access services outside of the discussion itself; they can, for instance, submit a prepared statement to the rest of the group and insert parts of the discussion into a personal file. They might also draw responses from a data-base system and enter them into the general discussion. Clearly, a level of interaction is thus reached that one does not find in face-to-face meetings where experts are cut off from their files and personal notes. Many questions remain to be answered when the application of such a tool in a management situation is considered. We have only begun to explore its potential in conducting structured conferences, in decision-making where voice channels and other media are available, and in coupling discussions with network services such as text-editing and data-base retrieval. The project has reached a stage where the impact of FORUM on workloads and communication patterns in the office environment and its effect in reducing paper documents and in saving the time of decision-makers can begin to be evaluated.

• Digital Speech Communication via the ARPA Network
1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by: Dr. Bernard Gold
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INTRODUCTION

ARPA is now sponsoring work directed towards packetized speech communications on the ARPA network. An important direction of this work is the development of speech processing modules wherein the special properties of the ARPA network are advantageously exploited.

An important ARPA network feature is the fact that packets undergo delays of varying length. Delays are a function of network loading and successive packets from the same source may travel via different routes and be delayed differentially. An important advantage of the ARPA network with respect to speech is the fact that the asynchronous nature of packet transmission is amenable to the use of variable rate coding of the speech. Thus for example, the incorporation of a silence detector within the speech processor could lead to substantial data rate savings.

SPEECH PROCESSORS

Lincoln Laboratory has performed research and development on speech bandwidth compression systems since 1960, and has constructed and simulated many speech processing systems. At present, Lincoln has a program in digital speech communications (supported partly by ARPA and partly by the office of the Assistant Secretary of Defense) concerned with digital speech communications at rates ranging from 2 to 16K bits.

Speech processing systems which depend on assumed models for the vocal tract and vocal cords are often called analysis-synthesis systems. Such devices have the property that time-varying parameters are extracted from the speech signal (analysis), transmitted, and then used to control the model. Because of the vocal cord-vocal tract separation the synthesized speech may be slowed down or speeded up by the simple expedient of expanding or contracting the time axis of the parameters. Unlike a tape recorder, which when it changes speeds causes a spectral distortion, the analysis-synthesis system will result in a stretching or compressing of the synthesized speech time axis. Thus, for example, an uttered vowel will have the same spectrum but will be longer or shorter in duration, and will thus maintain a high intelligibility level.

It thus seems that analysis-synthesis techniques can play an important role in the development of ARPA network speech processors by adapting the play-out rate of the buffered synthesizer parameters to the observed packet arrival times. Thus, if no new packets are arriving, the system can slow down and when packets arrive too fast, the system can speed up.

TYPES OF SPEECH PROCESSOR SYSTEMS

There appear to be two types of digital speech processing systems that are of potential use for the ARPA network. One type of system is a differential pulse-code modulation (DPCM) system wherein changes in the speech signals are "tracked" by digitally encoding the difference between the most recent estimate of the speech and the new value. Such systems appear to operate acceptably at about 16K bits and above - for

further rate reduction, analysis-synthesis systems appear to be the answer. DPCM signals cannot be time-distorted without spectral distortion - nevertheless, they are of interest for several reasons, as we shall see in the next section.

For rates in the range 8-12K bits, two devices seem to be most appropriate. One, the voice-excited vocoder is a classical channel

vocoder scheme with the excitation (vocal-cord) function being generated via a distorted version of filtered speech. The other goes under the name of adaptive-predictive coding and consists of finding a few important parameters of a formant speech model and sending these along with an error signal which can be used to excite a simplified synthesizer.

For rates in the 2-8K bit range, the two well-known systems are the channel vocoder and the linear predictive coding (LPC) system. The channel vocoder has been well established as a highly intelligible, albeit somewhat unnatural, speech device. At present LPC development is proceeding at a rapid pace but the definitive algorithms and associated hardware configuration have not yet completely evolved.

DPCM SYSTEM

Bob Kahn has requested that Lincoln aid ARPA in obtaining several 16K bit systems for early demonstrations on the ARPA network. Because of the high data rate, and inability to adapt to network traffic delays, these systems do not presently seem to be the appropriately long term solution to ARPA network speech processors. However, Dr. Kahn would like to establish, in a very short time, the viability of ARPA network speech communication by means of an actual, if limited, demonstration. DPCM systems are cheap, can be easily connected to the ARPA network and can be made available appreciably sooner than any other system. Lincoln is presently examining two varieties of such devices and hopes to have one of them "on the air" quite soon.

VOICE EXCITED VOCODERS (VEV) and ADAPTIVE-PREDICTIVE CODING (APC)

Channel vocoders built in the 1960's consisted of a large number of analog filters and were quite cumbersome, expensive and needed "tuning-up". By contrast, present-day digital filtering techniques make it possible to get the same performance much more compactly and cheaply. We are presently developing a simulation program on the fast digital processor (FDP), a high speed programmable signal processor built by Lincoln several years ago. Based on this simulation, hardware structures can be specified.

We have been promised a description of an APC algorithm by DCA, (Defense Communications Agency). When we get it we will first simulate it on the FDP to verify whatever claims were made and compare its performance with that of the VEV.

CHANNEL VOCODERS

Up to now, a large fraction of our effort has gone into channel vocoders. We feel that the algorithms for such systems are so well understood and have been so well authenticated by much listening that a digital hardware device can be built in a reasonable time. Thus, although most people in the speech business believe that LPC systems have a superior quality and will eventually win out, the vocoder can serve as an excellent stop-gap device.

At present, two hardware structures are being investigated, one using TTL hardware and separate multiplexed digital filters for each of the three required filter banks and the other using ECL hardware and a single fast digital filter to handle all three filter banks.

LPC SYSTEMS

The major thrust of the DOD speech processing effort has been directed towards LPC devices. Lincoln has presently simulated two partially complete LPC devices on the FDP. One is the so-called "direct form" whereby the vocal tract model is assumed to be a 12 pole direct form digital filter - the other is the "acoustic-tube model" whereby the parameters of a ladder form digital filter are derived in the analysis. The latter configuration has the striking advantage that digital filter stability can be easily checked and controlled. It is also likely that the "acoustic-tube" parameters can be transmitted at a lower rate, although this particular question has not been experimentally answered.

SUMMARY

Our intention is to develop speech processors for use with the ARPA network. At present, the potentially most interesting sets of such devices are speech analysis-synthesis systems. However, we also are in the process of helping to demonstrate a 16K bit DPCM system for a quick demonstration.

THE PRACTICAL IMPACT OF RECENT COMPUTER ADVANCES ON THE
ANALYSIS AND DESIGN OF LARGE SCALE NETWORKS

PREPARED FOR: ARPA IPT PRINCIPAL INVESTIGATORS CONFERENCE
LOS ANGELES, FEB 6-8, 1974

PREPARED BY: HOWARD FRANK
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NETWORK ANALYSIS CORPORATION'S CONTRACT WITH ARPA HAS
THE FOLLOWING MAJOR OBJECTIVES:

(1) THE DEVELOPMENT OF TECHNIQUES FOR THE ANALYSIS AND DESIGN OF LARGE COMPUTER NETWORKS FOR RESOURCE SHARING AND COMMUNICATIONS; (2) THE APPLICATION OF THESE TECHNIQUES TO STUDY THE PROPERTIES OF SUCH NETWORKS FOR USE IN STUDYING DEFENSE DEPARTMENT COMPUTER AND COMMUNICATION REQUIREMENTS; AND (3) THE APPLICATION OF RECENT COMPUTER ADVANCES, SUCH AS INTERACTIVE DISPLAY DEVICES AND DISTRIBUTED COMPUTING, TO THE ANALYSIS AND DESIGN OF LARGE SCALE NETWORKS.

THE FOLLOWING WERE MAJOR ACCOMPLISHMENTS DURING THE PAST YEAR:

A study of the effect of point-to-point and broadcast satellite channels on ARPANET cost and throughput was completed.

Investigations of large network routing schemes were continued including new routing methods for both high bandwidth and for partitioned networks?

A multiplexing experiment to obtain low cost leased line terminal access to ARPANET was successfully completed. Four CRT terminals are now operating on a single 4800 BPS line into ARPANET TIP.

The first phase of an interactive network data handling system has been completed for an IMLAC display editing system for large network graphics.

Part 1 of a study of network reliability and economics for a systems with 1000 nodes was completed.

A new large network design technique, based on "cut-saturation" was developed and found to be more cost effective than the branch exchange techniques currently in use.

The second phase of a study of terminal oriented network cost and performance was completed.

The definition of a network analysis problem solving system was completed. This includes system definitions for network data structure manipulation, network algorithm programming, and the first phase in the specification of a network programming language.

The first phase of a detailed, event oriented simulation model to develop flow control and routing algorithms was completed for the packet radio system.

A study of the combination of packet broadcast techniques and two way coaxial cable system for use in urban and suburban environments was completed.

Major progress was made in the development of flow control and routing techniques for packet radio.

RECENT TECHNICAL PUBLICATIONS ARE GIVEN BELOW. IN ADDITION, APPROXIMATELY 10 NEW PUBLICATIONS ARE PRESENTLY IN PREPARATION.

"TOOLS FOR PLANNING AND DESIGNING DATA COMMUNICATIONS NETWORKS," PROCEEDINGS OF THE NATIONAL COMPUTER CONFERENCE, MAY, 1974

"ON SPLITTING RANDOM ACCESSED BROADCAST COMMUNICATIONS CHANNELS," SEVENTH HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, JANUARY 8-10, 1974

"PACKET SWITCHING NETWORK DESIGN: A CASE STUDY," NATIONAL TELECOMMUNICATIONS CONFERENCE, ATLANTA, GEORGIA, NOVEMBER 26-28, 1973

"DETERMINISTIC AND ADAPTIVE ROUTING POLICIES IN PACKET-SWITCHED COMPUTER NETWORKS," PROCEEDINGS OF THE IEEE ACM CONFERENCE ON DATA NETWORKS, TAMPA, FLORIDA, NOVEMBER 12-15, 1973

"A UNIFIED ALGORITHM FOR DESIGNING MULTIDROP TELEPROCESSING NETWORKS," DATA NETWORKS: ANALYSIS AND DESIGN, THIRD ANNUAL DATA COMMUNICATION SYMPOSIUM, NOVEMBER, 1973

"COMPUTATIONAL CONSIDERATIONS AND ROUTING PROBLEMS FOR LARGE COMPUTER COMMUNICATION NETS," NATIONAL TELECOMMUNICATIONS CONFERENCE, ATLANTA, GEORGIA, NOVEMBER, 1973

"ISSUES IN THE DESIGN OF LARGE DISTRIBUTED COMPUTER COMMUNICATION NETWORKS," NATIONAL TELECOMMUNICATIONS CONFERENCE, ATLANTA, GEORGIA, NOVEMBER, 1973

"ROUTING IN COMPUTER NETWORKS," NETWORKS, JANUARY, 1973

"AVOIDING SIMULATION IN SIMULATING COMPUTER COMMUNICATION NETWORKS," NATIONAL COMPUTER CONFERENCE, 1973

"THE FLOW DEVIATION METHOD: AN APPROACH TO STORE-AND-FORWARD COMMUNICATION NETWORK DESIGN," NETWORKS, JANUARY, 1973

"TOPOLOGICAL OPTIMIZATION OF COMPUTER NETWORKS," PROCEEDINGS OF IEEE, NOVEMBER, 1972

"RELIABILITY CONSIDERATIONS IN THE GROWTH OF COMPUTER COMMUNICATION NETWORKS," NATIONAL TELECOMMUNICATIONS CONFERENCE, NOVEMBER, 1973

"RECURSIVE ANALYSIS OF NETWORK RELIABILITY," NETWORKS, JULY, 1973

14-JAN-78 Part of NIC 20766
NIC 20766
Part of NIC 20766

SUMMARY OF 1973 ACCOMPLISHMENTS BY SRI-ARC FOR IPTO 1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by: Douglas C. Engelbart, Richard A. Watson, James G. Norton
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INTRODUCTION

ARC has taken major steps toward two main goals:

- 1). Understanding and implementation of distributed system structures and the user interface for a knowledge workshop that provides a coherent, consistent, and flexible user window to a wide range of intercommunicating tools existing within a resource sharing computer network.
- 2). Obtaining wide application use of the evolving knowledge workshop within a framework of application to a variety of real work environments, analysis of the experience, development to yield an improving fit between needs and capabilities.

The steps taken toward these goals are described below.

DEVELOPMENT

NLS USER INTERFACE

ARC has achieved significant results in increasing the flexibility, ease of use, implementation simplicity and generality of the NLS user interface. Work has completed on design and implementation of a command language (CML) and command interpreter system allowing higher level language specification of the user interface. The user interface specification is compiled into a tree of instructions to drive the command interpreter, providing centralized command parsing and user feedback.

The approach taken allows experimentation with different command language structures and feedback, simplification of subsystem implementations, and adaptation of the user interface to individual preferences.

It also allows NLS "frontend" functions to be moved to a mini-computer. Such a move will benefit evolution of a knowledge workshop system using tools distributed over a network of nodes accessible with a coherent user interface from mini-computer controlled terminals. It will also cut hourly usage cost significantly, the expect to cut NLS usage cost in half in each of the next two years by this means. The approach has already yielded a 25% source code compaction and an increase in running efficiency.

Other changes include:

A cleanup and redesign of the command language to remove known inconsistencies, to add more novice oriented features, and to benefit from two years of Network experience.

Addition of a User Profile System to allow the user to specify NLS Private, default profile of optional user interface parameters.

Addition of more help facilities to provide either quick menu help or direct branching to complete, queryable documentation starting at a point related to an immediate problem. First level help cues are derived automatically from the CML specification.

A restructuring of NLS functions into clearly intercommunicating subsystems.

Addition of initial features of an NLS Macro or Programming facility. Present user-written programs in the L-10 programming language have been made readily accessible in a single directory.

DIALOG SUPPORT SYSTEM

The NLS Journal system has been integrated into the Network Mail system for both delivery and input, and we have taken a leading role in the creation of a Network Mail protocol.

We began design of a distributed Journal system and associated Network Protocols that will allow various Journal functions such as distribution, recording, cataloging, storage and retrieval to be on separate Network hosts. Besides allowing the Journal to run cooperatively on several Network hosts, this system work provides new insights into resource sharing techniques and concepts for Network Mail protocol evolution.

We implemented an initial system allowing Journal systems on two Network-based PDP-10s to work cooperatively.

Privacy Protection capabilities are being added to the Journal.

INFORMATION STORAGE AND RETRIEVAL

The NLS Query subsystem has been improved, to allow multiple NLS file data bases, and in its user interface. A subset of Query features are used in the help system incorporated in the new user interface.

Planning has begun for integration of NLS with Network data Management facilities such as the Datacomputer.

DISPLAY CONCEPTS AND TERMINALS

Steps have been taken to make the display version of NLS more easily available to Network users. Since 1972 it has been available from INMAC terminals. In 1973 we developed an inexpensive micro-computer box, called a Line Processor.

The Line Processor and associated software allow low cost mass-produced alphanumeric displays to be used without modification with a House and a Keyset (connected to the Line Processor) as two dimensional Display NLS terminals. An important aspect of this work was the extension of the NLS virtual terminal concept and development of associated communication protocols. The results were also used in the Network Graphics protocol.

Arrangements have been made to have Line Processors commercially manufactured for about \$1500 apiece. The first Network usage of

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NIC 20700
Part of NIC 20414

Editing and publishing assistance was given for the online and offline versions of the AI Newsletter.

NEW ACCOMPLISHMENTS

Line Processor supported alphanumeric terminals is expected this spring.

Participated actively with the Network Graphics Group in the development of the proposed Network Graphics Protocol.

OPERATING SYSTEM

The backup file archival and dump system, BSYS, developed at AHC, was released to the Tenex community.

A group allocation system allowing controlled access to the system on a login slot basis was built and put into operation and released to the Tenex community. This system allows the user population to be split into groups and each group assigned a given quota during different time periods during the day. An express login capability for short tasks such as printing a file or reading one's mail is also part of the scheme.

Tenex changes necessary to support the typewriter version of NLS have been incorporated into the standard BBN-released Tenex to allow future support of NLS on any Tenex. Similar work to support the display version of NLS from standard Tenex is proceeding.

NEW NLS SUBSYSTEMS

A number of new NLS subsystems have been built, a calculator that allows operands and results to be obtained and placed in NLS files, either by interactive selection or by RLD programs; an offline text entry and editor using magnetic tape cassettes; some Tenex level functions (such as file system and FTP manipulation operations); have been made available at the NLS user level; and source level debugging facilities.

APPLICATIONS

KNOWLEDGE WORKSHOP UTILITY

A contract was initiated to have Tymshare install and operate a PDP-10 to run NLS for Network exploratory application of NLS-based knowledge workshop technology. Tymshare personnel have been trained in Tenex maintenance. ARPA-IPT has subscribed in a separate contract to 60% of the expected capacity, and has installed a IIP at Tymshare.

NET-GEN INFORMATION CENTER

ONGOING ACTIVITIES

Editor support service was provided to the Network user community, principally through the RFC mechanism and through the Journal and Catalog systems.

Reference support service was provided to the Network user community, principally through the Resource Notebook (both online and offline), and through distribution of Network Protocol documents to sites, associates, and other requestors.

Information was provided to visitors interested in an understanding of the Network's technology and resource composition.

Participation was carried on in Network working groups pertinent to protocols, and users' needs and interests.

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A new "paperback" ARPANET Directory was designed, published, and distributed.

The ARPANET News, under editorship of MITRE's Jean Iscari, was published and distributed by NIC on a regular basis both online and in hardcopy. The NIC also contributed editorial assistance.

The Official Network Hostnames were streamlined out in major undertakings, published, and a list maintained with help from Nancy Adams of BBN, and Vint Cerf of Stanford.

Significant contributions were made to the establishment of overall design criteria for both the NLS HELP system and the ALC QUERY system, a mechanism for browsing through and selecting particular pieces of information from highly structured files of general interest, such as the Network Resource Notebook.

The NIC's operations were quantitatively analyzed, to determine costs and scope of operations. Goals, problems, and requirements of the NIC were described in the framework of its then present (Fall '73) vector, in order to stimulate active discussions of, and decisions about, the NIC's future role. It has been proposed to serve the whole-net user population with a set of simplified basic services to be paid for from Network overhead funds and to consider special sets of modular services for special-interest ARPANET user communities to be separately negotiated and funded.

ANALYSIS

A new function within AHC, called Analysis, has been established to develop and publish methodology for analyzing workshop systems such as NLS in all their aspects, system operation, user needs and usage patterns etc.

Publish results of the studies of existing operational experience. Feed results back to developers for further system evolution.

Initial studies have been started in the areas of system and usage economics and usage patterns, command timing and usage frequency, and comparison between systems.

1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

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Our activities over the six months of our ARPA Contract have been directed to getting our node operating smoothly. Our TIP arrived in July, and the interfacing to our front-end PDP-9 was completed in August. By the time the telephone arrived in September, all was ready to put the Rutherford Laboratory (RL) IBM 360/195 on-line in a crude way. Both the RL and US Hosts were demonstrated successfully at the NATO September School on Computer Networks, and Doug Engelbart gave an extremely successful NIC course the following week to potential UK users.

A major activity over the whole period was obtaining the complex set of approvals from European PTTs required to use telephone lines on a shared basis. Final approval was obtained only from 1 November when the node became available publicly to approved users over the switched telephone network. Further negotiations are still in progress on putting in a leased line to Germany, and a satellite IMP in the UK groundstation in Goonhilly (for Aloha type experiments).

Technically our main accomplishment was in attaching the RL IBM 360/195 in such a way that no resident software was required on the RL machine. We at UCL have a PDP-9 which is a local host to the TIP. In the PDP-9 we have the Host-IMP, Host-Host, ICP and Telnet protocols; we translate these to do multi leaved HASP RJE and Interactive protocols required for remote usage of the RL machine. Much more work needs to be done to make the front-end system more rugged and to incorporate an FTP, but we have demonstrated that the approach is successful.

A considerable effort has gone into the provision of documentation - though much more needs to be done. We have put a number of HELP files in the PDP-9 to help remote users of the 360. On the other side, for UK users, we have started setting up a documentation facility. A catalogue of our document collection is kept on-line on the NIC at SRI; the documents themselves are stored and distributed by the British Library (Lending Section). That organization is professionally equipped to disseminate

documents, and we feel its involvement is both economic and desirable. As part of this class of service, we have also developed a mail sorting and reading system which has considerable advantages over those available elsewhere on the ARPANET; it runs at BBN and ISI.

We have started getting together a number of ARPANET user communities at different UK universities and Research Establishments. This has required setting up a mechanism for approving their use and supporting technically their attempts to use ARPANET. The most active users so far have been on Algebraic Systems (Barton, Cambridge), MEDLINE, (Harley, British Library), Languages (Laski, Essex U) and documentation (Wilbur et al., UCL). However, a number of other important groups like Seismic Research, Medline use in a number of medical schools, high-energy physics, computer-aided design applications, languages and teleconferencing are planned for 1974.

We have started to provide limited services to US workers on the 360/195; this is only starting and will expand considerably during 1974.

An important activity, on which there has been some discussion but little real work so far, has been on Inter Network Protocols. Here our group will become involved with others in the US in cooperative experiments, and will be active also as liaison on related experiments between the French Cyclades and the UK NPL networks and the UK Post Office, Experimental Packet Switched Service.

Several papers and talks on ARPANET have been presented by our group, both in the UK and elsewhere.

I would regard our activities in 1973 as having laid the foundations for the UK groups being active and useful participants in the ARPANET community.

1973 ARPA Project Summary

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Los Angeles, February 6-8, 1974

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AUTOMATIC PROGRAMMING. (R. Balzer). This project is studying domain-independent Automatic Programming. This is a two-stage process involving first, the acquisition of the structure of a problem domain from an expert specifying what actions exist in the domain, what preconditions exist, what constraints have to be satisfied in the domain, what objects exist and what their descriptions are. The second stage uses this structural description of the domain to transform a high-level imprecise description of a process into a detailed program consistent with the constraints and limitations of the domain, with the focus on the amount of impreciseness and flexibility which can be tolerated in the specifications of the process and domain.

The system is based on a relational data base to store and manipulate the specifications. The data base routines have been implemented as has the interpreter for the language generated by the AP system. A first crude version of the second stage is being tested. (See "Domain-Independent Automatic Programming, ISI-RR-73-14.")

PROGRAM VERIFICATION. (R. London, D. Good). To verify a computer program means to demonstrate the consistency between the program and specifications or documentation of what the program is to do. The Program Verification Project is building software tools to aid in the construction of verified programs. Already running are verification condition generators for two programming languages. Algebraic simplification and interactive theorem proving of the lemmas, produced by the verification condition generators, are being accomplished using Reduce and the Bledsoe Theorem Prover. A symbolic executor for Pascal programs is being written. The benefits of modular and structured programs are being exploited to make the verification of such programs easier, convincing, and understandable. Current plans are to develop these components, now fairly disjoint, into a smoothly integrated system for constructing verified programs, and to test the credibility of the system on significant, real programs.

NETWORK VOICE. (D. Cohen, R. Cole). The overall goal of this project is to reduce to practice voice communication on the ARPANET. The project is studying means to deal with the effects of a packet switched network on continuous speech signals in interactive communication. The project is developing ways of partitioning, buffering and reconstructing digital and compressed voice signals to provide the appearance of continuity while minimizing delays. Speech compression algorithms produced by the speech research community will be implemented for real-time use on an SPS41/PDP-11-45 voice processing facility recently installed at ISI. The PDP-11 is being connected to the ARPANET as a host and will provide means to test the effectiveness of segmentation algorithms in dealing with the variable delay characteristics of the ARPANET. The voice processing facility will be used, in the near term, to develop "real time" versions of speech compression algorithms developed elsewhere within the ARPA community. The 11-45 will also be used to model network characteristics so that controlled experiments on segmentation algorithms can be run with known Net parameters.

INFORMATION AUTOMATION (D. Destreicher). The Information Automation Project is currently in the design phase of a telecommunications task conceived to aid the military and ARPANET users. The goal is to implement an on-line message handling system, which will be amenable to computer-naive users. The initial study for this task investigated the user style and functional requirements of a large multi-service military community. The results of this study are available in ISI/RR-73-12, an ISI report entitled "A Plan for Consolidation and Automation of Military Telecommunications on Oahu." The functional specifications for this system include message preparation (creation, editing, coordination), message transmission (routing, release, status query), and message reception (priority delivery, sorting, scanning, forwarding). Additionally the system will support off-line report generation and message archives. The research goal of the IA Project is to develop the necessary human-factors methodology needed to introduce interactive computer terminals into office environments. The project thesis is that current systems technology will suffice for many of the current automatable problems, and what is required is a collection of techniques to make the computer acceptable and useful to non-technical personnel. The target system, called Communications Network Nodes Effectuated by Computer Terminals (CONNECT) will be implemented on TENEX and the ARPANET at ISI. It is expected that an experimental system providing the above functions will be available to ARPANET users by January 1975.

PROGRAMMING RESEARCH INSTRUMENT. (L. Gallenson, L. Richardson). The PRIM project's current goal is to create a time-shared microprogramming facility. This facility will be accessed via the TENEX system on ISI's PDP-10.

The MLP-900 is a vertical word synchronous 250 ns cycle time microprocessor with 4K words of writable control store. Target space will be in the shared PDP-10 core.

The date for introduction of users is March 1974. At that time, users will be able to edit and compile MLP microcode in a high-level assembly language on TENEX and run these programs on the MLP. Debugging facilities on the PDP-10 and MLP will also be available. Initially, the MLP will operate with a single user; it will be available to several users on a time-shared basis later in calendar year '74.

The MLP/PDP-10 interface has been completed and is currently being checked out. The MLP provides a user/executive mode of operation with the appropriate protection of resources and the ability to swap context. A higher language micro-code compiler, General Purpose Microprogramming Language, GPM, has been completed and is currently in final check out. User documentation (PRIM Overview, PRIM Users Guide, MLP-900 Reference Manual, and GPM Manual) will be available to potential users by March 1, 1974.

PROTECTION ANALYSIS PROJECT. (R. Bisbey, J. Carlstedt). This project is concerned with evaluation methods for operating system security: specifically, with developing a useful methodology which can become sufficiently reliable, powerful, and cost effective to be used as a production tool for evaluating the secureness of operating systems. Initially, the project has focused on the identification and categorization of protection or security errors. A first activity started an empirically based collection of "error patterns", for a "cookbook" approach to evaluation which has already been applied successfully. A second activity has identified classes of errors through a more deductive approach. The next step is the expansion of the sets of collected errors and derived error patterns and the development of an "error-pattern-driven" evaluator for finding instances of errors of the given patterns in operating systems.

INSTITUTE TERMINAL SYSTEM. (L. Gallenson). ISI has defined an Institute terminal display system. A contract has been let to provide implementation by August 1974, to support the ARPA research programs at the Institute. The specifications provide for personal, general purpose terminals based on T.V. techniques capable of displaying line drawings and a full page of text, nominally 54 lines of 80 characters, in a high resolution format. Each terminal is associated with a writable font character generator allowing up to 256 variable size character descriptions and storage for up to 8K characters in a refresh memory. Copies of the specifications are available to interested readers. Discussions with other interested ARPA contractors aided in setting up the initial specifications. Currently, we are working with several ARPA contractors and the Net graphics protocol group in further definition of protocols and command languages at several levels.

PORTABLE TERMINAL RESEARCH. (R. Parker). Development of a prototype portable terminal for use with the ARPANET has been completed and the prototype has been in service in the Washington office for several months. This terminal is housed in a small briefcase style enclosure 10" x 14" x 6" and weighs about 20 lbs. It has a display capability

of 256 characters, upper case only, and connects to any standard telephone handset via a built-in acoustic coupler for communication to the Network. Second generation portable terminals will involve two divergent research vectors; one will concentrate on larger visual context, explore the fields of liquid crystal and plasma displays provide upper and lower case capability and continue to emphasize portability, while the other research vector will concentrate on the absolute minimum communication terminal.

XEROX GRAPHICS PRINTER (XGP). (T. Boynton, R. Parker). Development is in progress on two Xerox Graphics Printers (XGP) each to be driven by a PDP-11/40; they are designed to provide two modes of hardcopy output. One mode will provide very high resolution at a slower print speed and the other mode will provide fast, lower resolution copy. One system will remain at ISI and the other will be delivered to the ARPA office in Washington. Operation of the system involves PDP-11/40 for "raster-izing" data received via a 2400 baud TIP Network connection and presenting it as digital video with sync to the XGP. Single speed XGP implementation is nearing completion and follow-on development will provide multiple speed capability within a few months.

RESEARCH RESOURCES. (T. Boynton). The primary activity has been the TENEX resource at ISI. Since ISI cannot use the entire KA resource, it is shared with NET users. We have emphasized BBN TENEX and stressed the internal and external need for maximum commitment from the resource. We have scheduled 7 day/week, 24 hour/day, operation minus time for system maintenance. The system has been stressed from overuse by the almost constant user queue. With the load on the system, user response has been poor for all; however, a great deal has been learned from the prolonged stressed condition. It will be reflected in the KI-KA (one processor backup) system targeted for January 1974. From our experience stems solid plans for greatly improved total system reliability which will be reflected in a greatly reduced maintenance window, an assured backup processor, and compatible KA, KI software.

COTCO EFFORT. (R. Stotz). As a special effort for ARPA-IPT, ISI personnel performed a study and prepared a report providing a plan for consolidation and automation of all military telecommunications on the Island of Oahu. This report, transmitted via ARPA to the Joint Chiefs of Staff, recommends an architectural concept which will provide complete writer to reader automation of message communications for some 6,000 action officers at 24 military bases on Oahu. It would provide the reliability and continuity of service required while lowering costs and virtually eliminating the intolerable delays now experienced in the manual system. This plan, based on technology developed by IPT over the last several years, has had a significant impact on DoD planning for the environment studied and should influence other installations, worldwide.

UCLA COMPUTER NETWORK RESEARCH

1973 ARPA Project Summary

Prepared for: ARPA IPT Principal Investigators Conference
Los Angeles, Feb 6-8, 1974

Prepared by: Leonard Kleinrock
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Our contract is concerned with MEASURES, MODELS and MEASUREMENTS for computer systems and networks. The common element in all of the systems we study is that they are finite-capacity resources which are accessed by unpredictable demands. The situation naturally creates conflicts, congestion and competition which we study. Our goal is one of performance evaluation and a resulting methodology for system analysis and design.

Below, we report briefly on four accomplishments and one event for 1973. The accomplishments are: network measurements; highly improved models for operating systems; good progress in packet switching studies (satellite and ground radio); and network design procedures. The event concerns our facility.

(1) The Network Measurement Center (NMC) at UCLA has grown significantly in size, goals and accomplishments. We have a carefully documented measurement plan which takes us forward to July, 1975 (of course with room for new experiments) and includes some very exciting experiments. We have measured the network behavior a number of ways and our most interesting results are the week-long measurements on the whole net. We have prepared a paper for the AFIPS NCC which summarizes the results of these measurements. Some very revealing phenomena have been identified, including the fact of tiny messages, incest, favoritism, peakedness and levels of utilization, delay, usage, etc. Our other experiments include: the measurement of the maximum throughput of the network (for individual node-pairs as well as for the entire network); routing table change measurements to identify "natural" partitioning in the net; and "network-breaking" experiments (we have been "successful" here once by "malice" and once by "innocence"). We are also preparing to cooperate with Lincoln and ISI on some speech measurements.

(2) We have developed analytical models for operating systems which permit us to study multiple resource systems (as opposed to single resource systems as in the past). These turn out to be extremely useful. For example, we have shown that complex queueing network models may be decomposed into isolated node-by-node configurations which can then be studied in isolation. The analysis shows that some very meaningful measures of system performance depend only upon mean values of the underlying distributions, and these measures are given explicitly. The applications are beginning to be exploited.

(3) Satellite packet switching studies have progressed very nicely. We established that systems of the slotted ALOHA type are fundamentally unstable, have studied the problem, and have found optimum control methods for stabilizing them. The research in ground radio packet switching has moved ahead well also. We understand the details of how a carrier-sense system will function in the Packet Radio environment, and how disastrous the effect of hidden terminals can be. To get around this, we have analyzed the solution using a busy tone, and find it to be effective. The throughput with a well-designed carrier-sense system can far exceed the pure or slotted ALOHA systems (non-sense systems!).

(4) Our analytic studies of computer networks has led us to an efficient procedure for network design. This design methodology is quite effective, although many design questions remain under study. Currently, we are making headway into large network design and routing problems, and bringing some of our measurement experiments into this study.

At the end of 1973, we got rid of our Xerox Sigma-7 and have replaced it with a DEC PDP11/45 system which will run ANTS for us. We also intend to create a virtual machine monitor for the 11/45 (the implementation is straightforward, relatively easy, and well along to completion). The virtual machine monitor will exist in a mathematically proven secure system which takes advantage of the hardware protected kernel state of the PDP11/45 and guarantees no illegal access among all virtual machines. We hope to extend this approach to investigate some of the security questions of the ARPANET. Now we are completely dependent on the network for all services including: computing, storage, text preparation, network measurements, measurement data reduction, etc, etc, etc.

OVERVIEW OF IPT SPONSORED RESEARCH AT THE
UCSB-COMPUTER SYSTEMS LABORATORY, . . . , 1973

SERVER AND USER SITE DEVELOPMENT

Modifications to 360 MCP,
The 360/370 MCP has undergone refinements which include billing for
traffic, variable length reads, intra-host connection of processes,
measurement of overhead for MCP operation, and surveyor,
Logger and De-Bugger,
Two new facilities were added to the 360 system software that allow
developmental work to be carried on in a "virtual" manner. New network
programs can be brought into the 360 and de-bugged during prime-time
without affecting overall systems operation.
User and Server FTP,
Users of the on-line system may now transfer text files between
FTP servers and the OLS-COL file system. Also a PL-1 user FTP which
runs in batch was added. An internal FTP server was added to accept
mail and print files. The mail or files may be accessed on-line
or directed to a line printer through MASP.

INTERNAL NETWORK SUPPORT, COLLABORATION, AND CONSULTATION

MCP Exportation,
The 360 MCP has been made exportable and during the last year it was
adopted and modified for use on VAX (370/15P) and SDC (370/145).
Speech Data Base Experiment,
Using a sample speech dictionary provided by SCHL, an experiment in
interactive file access was carried out on the 360-75 using the IBM
Information Management System (IMS-2). It was found that the amount
of storage required to run such a system was prohibitive.
Network Resources Summary,
This compilation of available Network services is arranged according
to areas of application. It is now being made a part of an overall
Network guide to services.

SIGNAL PROCESSING

Modifications to SEL-3100 Signal Processor,
The adaptive interactive signal processing system is being modified
for multiple console use, including network access. In addition to
running local analysis and from the network, users will have access
to the Collier-Harrison signal processor as well.
Monitoring and Real-Time Data Transfer,
Programs were added to the SEL system and its TCP to allow the movement
and resumption of forced serial data to other network sites,
following the experiments carried out earlier this year, modification
of the program and addition of special I/O hardware for transfer of

NETWORK APPLICATIONS

Image Processing.....

Acoustic and Holographic Images produced at UCSB are being digitized at USC and brought over the Net into the 1800 Image processor at CSL. Stored in this machine they are accessed from consoles on either the 1800 or the SEL. Under direction of the researcher at a graphics console computation can be invoked in the SEL or at the 350. Soon the CHI signal processor will also be available.

Information Resources.....

Terminals at UCSB are being used to access MEDLINE by way of the Network and many of the other information services available on the west coast by way of tie-line connection. Introduction of users to the available resources may help to bring other library files onto the Network.

Experiments in Resource Sharing.....

Students and researchers at UCSB are collaborating with other sites to bring about results not easily obtained independently. For example the results of computation at MIT-MATHLAB are passed over to the UCSB On-Line System for graphics display.

Cooperative Graphics.....

Experimentation is on-going in the area of graphics "conferencing" between UCSB and Illinois, using IMLAC terminals and the GLS.

Plasma Terminal Use (PLATO).....

A prototype unit was developed that allows the attachment of an Illinois Plasma Terminal to the ARPANET. The terminal can operate as a standard ASCII unit on the Net and as a PLATO-driven terminal as well. Another hardware adaptor has been inserted between the Illinois PLATO system and the ANTS/11. Experimentation is presently underway to assess the impact of the Network on its operation. A micro-processor front-end is also being implemented for the terminal.

DIRECT SUPPORT TO OTHER NETWORK SITES

Very Distant Host (VDH) Development.....

The installation of the VDH/11 at SCRL was completed on their 11/20 and subsequently on the 11/45. Diagnostic routines for the hardware and a total programming system were completed. VDH/11 units are being placed into operation at Stanford, Haskins Laboratories, and Berkeley (See NIC 16479 and 19242).

IMP Attachments for 362/370 Systems.....

Two more installations were brought on the Network using the UCSB INTERFACE-IMP/360 Hardware. These units were added at SDAC (362-44) and RAND (370-158).

NIC RELEASES SUMMARIZE CSL WORK

| | | |
|-----------|--------------------------------------|-----------|
| NIC 13700 | Announcement of RJS at UCSB | Krillanov |
| NIC 13701 | Data Reconfiguration Service at UCSB | Faeh |
| NIC 14022 | Remote Job Service at UCSB | Krillanov |
| NIC 16763 | MIX and MIXAL at UCSB | Pickens |
| NIC 19355 | Surrogate RJS for UCLA-CCN | Pickens |

| | | |
|-----------|---|------------------|
| NIC 16117 | IBM System 360 (370) to IMP-Inter, Install, Planning | Bryan |
| NIC 16117 | Real-Time Data Transmission on the ARPANET | McAfee & Pflafer |
| NIC 16400 | Griffly-The Very Distant Host for ARPA-Style Nets | Bryan |
| NIC 16617 | ARPANET Accounts | Vaughn |
| NIC 16618 | Resource Evaluation | Pickens |
| NIC 17151 | MIT-MATHLAB Meets UCSD-QLS, An Examp, of Res, Sharing | Pickens |
| NIC 17791 | Of What Quality be The UCSD Resource Evaluation? | Pickens |
| NIC 18973 | Experimental Input Mapping Between NVT-ASCII and UCSD On-Line System | Pickens |
| NIC 19144 | Announcement of a Mail Facility at UCSD | Krillanov |
| NIC 19386 | WASP System Operators Guide | Krillanov |

NIC 20962
PART OF NIC 20414

THE ALOHA SYSTEM
1973 ARPA PROJECT SUMMARY

PREPARED FOR: ARPA IPT PRINCIPAL INVESTIGATORS CONFERENCE

LOS ANGELES, FEBRUARY 6-8, 1974

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THE ALOHA SYSTEM

FRANKLIN F. KUO, NORMAN ABRAMSON
CO-PRINCIPAL INVESTIGATORS

OUR WORK IN THE ALOHA SYSTEM IS DIVIDED INTO TWO TASKS:

TASK I: TO DEVELOP NEW METHODS AND PROTOCOLS FOR RANDOM ACCESS
RADIO COMMUNICATIONS FOR COMPUTERS.

TASK II: TO STUDY SYSTEMATIC DESIGNS FOR MULTIPROCESSOR COMPUTING
STRUCTURES THROUGH THE DEVELOPMENTS OF THE BCC 500 SYSTEM.

WE WILL DISCUSS THE ACCOMPLISHMENTS BY TASK.

TASK I

THE WORK IN TASK I IS DIVIDED BETWEEN RADIO (GROUND) AND
SATELLITE COMMUNICATIONS.

RADIO COMMUNICATIONS: IN THIS AREA OUR PRIMARY WORK WAS PART OF THE
OVERALL EFFORT OF THE PACKET RADIO GROUP UNDER THE DIRECTION OF
R.E. KAHN OF ARPA. OUR ACCOMPLISHMENTS WERE IN THE FOLLOWING AREAS:

1. THEORETICAL STUDIES. NEW RESULTS WERE DERIVED ON THE SPATIAL
CAPACITY OF A RANDOM ACCESS (ALOHA) CHANNEL IN THE PRESENCE OF
PERFECT CAPTURE. A SECOND STUDY WAS COMPLETED COMPARING THE
THRUPUTS OF SPREAD SPECTRUM VERSUS ALOHA MULTIPLEXING TECHNIQUES.
2. SIMULATION STUDIES. A STUDY WAS COMPLETED COMPARING THE ADVANTAGES
OF NEGATIVE AND POSITIVE ACKNOWLEDGEMENT SCHEMES IN A PACKET
RADIO ENVIRONMENT. THIS STUDY IS PART OF AN EXTENSIVE SIMULATION
EFFORT WHICH IS NEARING COMPLETION IN WHICH WE HAVE PUT TOGETHER
A MINICOMPUTER FACILITY WHICH WILL ALLOW VALIDATION AND DATA
COLLECTION FOR DIFFERENT CHANNEL ORGANIZATIONS.
3. RADIO SYSTEM STUDIES. DURING 1973 RADIO SYSTEM STUDIES WERE
UNDERTAKEN WHICH WERE COMPOSED OF MEASUREMENTS OF CERTAIN CHANNEL
AND SOURCE CHARACTERISTICS OF THE ALOHA PACKET RADIO FACILITY
AND INVESTIGATIONS OF MODULATION METHODS AND ANTENNA
CONFIGURATIONS FOR PACKET RADIO CONFIGURATIONS.
4. PACKET RADIO TEST FACILITY. THE MAJOR DESIGN EFFORT IN 1973
WAS TO DESIGN AND BUILD A PACKET RADIO REPEATER. WITH THE
REPEATER OPERATING SUCCESSFULLY, INTERISLAND COMMUNICATIONS ON
THE ALOHA RADIO NET BECAME POSSIBLE FOR THE FIRST TIME.
ANOTHER IMPORTANT DESIGN EFFORT WAS THE DESIGN AND IMPLEMENTATION
OF A PROGRAMMABLE TERMINAL CONTROL UNIT (TCU) INVOLVING AN
INTEL 8008 MICROCOMPUTER ON A SINGLE INTEGRATED CIRCUIT CHIP. THIS
INTEGRATED TCU SERVES AS A MODEL FOR THE PACKET RADIO GROUP.

SATELLITE COMMUNICATIONS: IN SATELLITE COMMUNICATIONS WE HAVE BEEN INVOLVED IN A JOINT STUDY WITH ARPA, BBN, AND UCLA TO INVESTIGATE THE THEORY AND TO DESIGN THE PROTOCOLS FOR PACKET COMMUNICATIONS VIA BROADCAST SATELLITE. THESE STUDIES HAVE BEEN VERY FRUITFUL FOR ALOHA RESEARCHERS AND ARE DESCRIBED IN A SERIES OF ARPANET SATELLITE SYSTEM NOTES 22, 26, 29, 30, 32, 36 AND 37. IN THE SECOND SATELLITE PROJECT WE ARE INVOLVED IN, WE ARE DEVELOPING A SMALL GROUND STATION FOR EXPERIMENTING WITH THE NASA SATELLITE ATS-1 ON A BROADCAST MODE. WE HAVE DESIGNED AND BUILT EQUIPMENT FOR THE GROUND STATION WHICH ARE BASED ON THE ORIGINAL ALOHA SYSTEM HARDWARE. A PROTOTYPE GROUND STATION IS IN OPERATION, AND A RANDOM ACCESS BURST CHANNEL IS NOW IN OPERATION BETWEEN HONOLULU, AND NASA/AMES. SHORTLY WE WILL BE CONNECTED TO ALASKA, JAPAN, AUSTRALIA, AND NEW ZEALAND.

TASK II

ALMOST ALL OF THE TASK'S EFFORTS WERE DIRECTED TOWARDS COMPLETION AND EXPANSION OF THE BCC 500 COMPUTER HARDWARE AND SOFTWARE.

MOST OF THE HARDWARE OF THE 500 HAS BEEN REBUILT OR REFURBISHED WITH FASTER, MORE RELIABLE CIRCUITRY. DOCUMENTATION PROCEEDED IN PARALLEL AND BY THE END OF 1973, BOTH HARDWARE AND DOCUMENTATION WERE IN A GOOD STATE, AND THE SYSTEM WAS USABLE ON A LIMITED BASIS.

THE MAJOR TASK OF THE SOFTWARE GROUP WAS TO DEBUG THE LANGUAGE SPL AND THEN TO REWRITE AND RECOMPILE THE OPERATING SYSTEM USING THIS REFURBISHED AND MORE ROBUST VERSION OF SPL.

A NETWORK CONTROL PROGRAM WAS WRITTEN ENTIRELY IN MICROCODE TO BE RUN ON ONE OF THE 500 MICROPROCESSORS. THIS IS A NEW INNOVATION INASMUCH AS MOST OF THE ARPANET'S NCP'S HAVE BEEN IMPLEMENTED IN SOFTWARE ONLY.

A NEW MICROPROCESSOR WAS DESIGNED TO FUNCTION AS A COMMUNICATIONS CONTROLLER FOR THE ILLIAC SYSTEM.